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NAJAS MINOR ALL. IN NORTH AMERICA¹ JOUKO MERILÄINEN

Najas minor and *N. gracillima* are somewhat similar in appearance, and their distributions in part overlap. Misidentification by collectors of the rarer species, *N. minor*, is therefore possible. Closer investigation shows, however, that the species are easily distinguishable at any time. Confusingly similar are the narrow leaves and truncate to auriculate sheathing leaf bases. In the latter respect, *N. minor* and *N. gracillima* differ from all the other naiads occurring in North America (except *N. graminea* Del., a tropical introduction to some Californian rice fields).

Seed coat characteristics are conspicuous and visible through the transparent fruit wall, as seen in figures 9 and 10. The areolae can be seen best in dried material, while most other vegetative characteristics are best studied in fresh or resoftened material.

The overall plant size varies greatly in both species. The tallest individuals of *N. minor* are probably those collected by Lauterborn from the Rhine River, Germany, which he

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[Research done in 1963-64: In editing this study, the three papers on *Najas minor* All. that have come out since then (Fore and Mohlenbrock 1966; Stookey, Fore, and Mohlenbrock 1964; and Winterringer 1966) were added to make this study more useful. H. H. I.]

TABLE 1

Helpful characteristics in identification of *Najas minor* and *gracillima*

	<i>minor</i>	<i>gracillima</i>
COLOR (fresh)	Dark green. ²	Light green. ³
LEAVES	Recurved. Terminal internodes becoming shorter, the leaves tufted at top of branch giving a bushy habit (Fig. 1).	Not recurved. ⁴ Internodes about equal in different parts of plant, no bushy habit (Fig. 2).
	Leaf margin curvy . Base of spinules many -celled (Fig. 22-25).	Leaf margin rather straight . Base of spinules few -celled (Fig. 26, 27).
	Leaves broader, the spinules usually apparent without hand lens.	Leaves very narrow, the spinules usually not visible with the naked eye.
SHEATHING BASE	Truncate to auriculate. Rounded. Spinules continuing some distance down shoulders of sheath (Figs. 18, 19).	Truncate (rarely to auriculate). Less rounded. Spinules generally above shoulders only (Fig. 20, 21).
FRUIT	Style relatively long (Fig. 4, 7, 8).	Style relatively short (Fig. 4, 10, 12).
SEED	Areolae of seed coat transversely elongate (Fig. 5, 8, see uppermost cell layer of seed coat in Fig. 14, 15, 16).	Areolae of seed coat longitudinally elongate , sunken (Fig. 10, 17).

²Exception: Baumann (1911, p. 161) “. . . Polster von dunkelbrauner Farbe” in the Lake of Constance (Bodensee) in Central Europe.

³Exceptions: a) Fernald & Long 12521, William Co., W. Va., dark green (GH). See Fernald 1947, p. 106 and Clausen 1947, pp. 335-336. b) Seymour 4450a, Bristol Co., Mass., dark green (NEBC).

⁴Difference visible only in fresh or carefully pressed material.

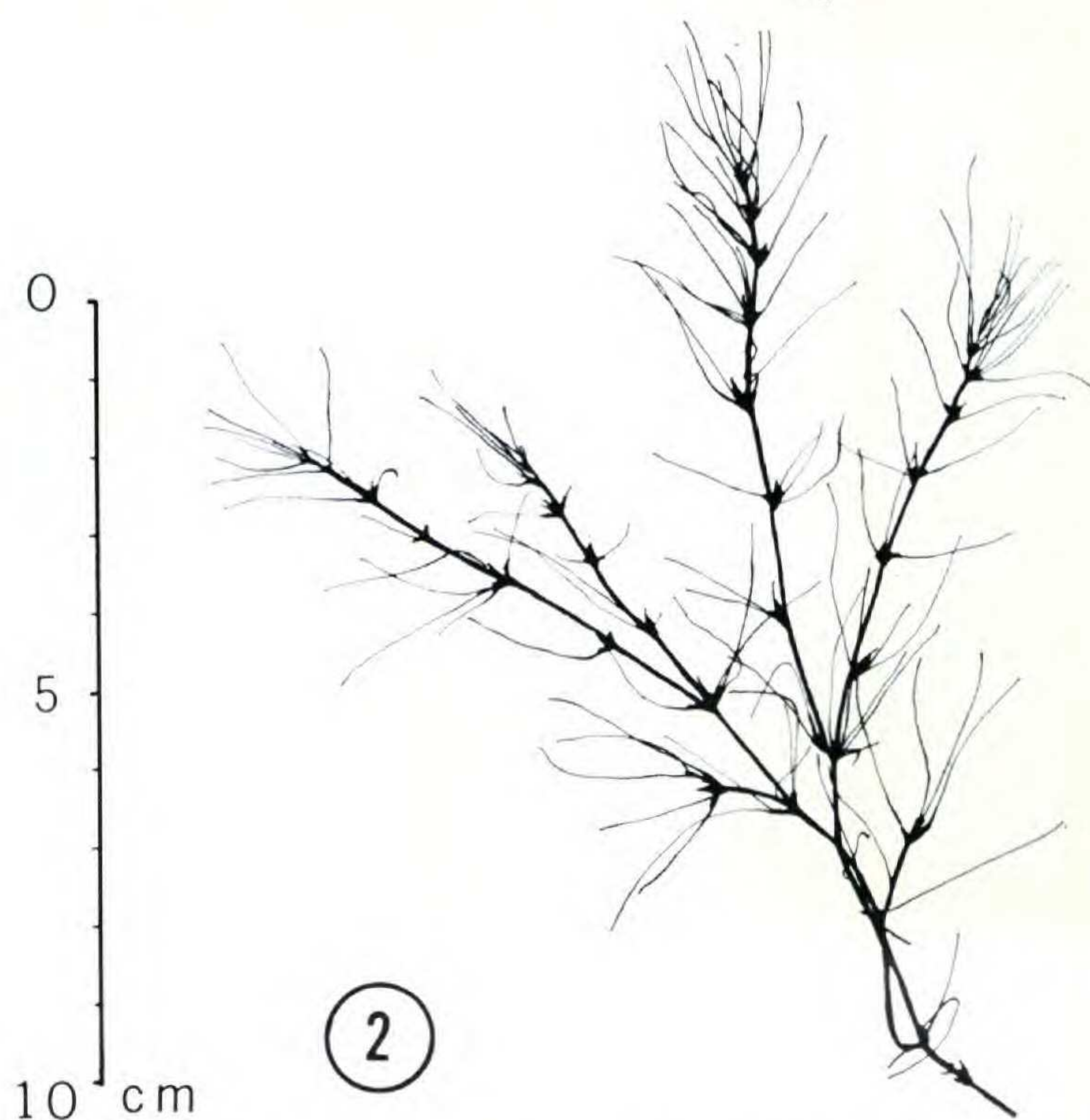
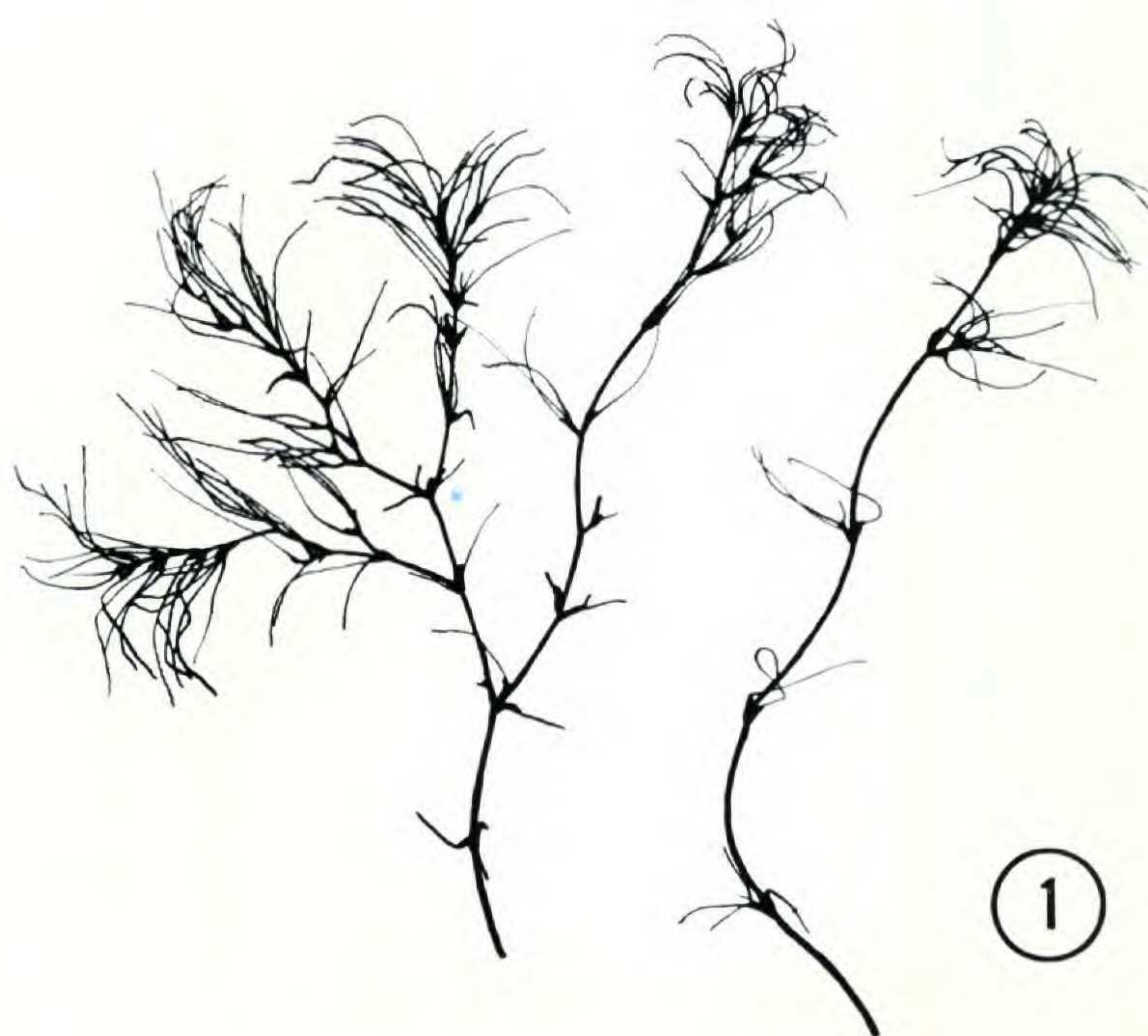


Fig. 1. *Najas minor*: Pennsylvania, Bedford Co., shallow water, 3/4 miles south of Schellsburg, Aug. 27, 1962, *Bergheimer 21371*. (Drawing from photograph).

Fig. 2. *Najas gracillima*: Massachusetts, Norfolk Co., Avon Reservoir, Sept. 22, 1937, *Seymour 5023*. (Drawing from photograph).

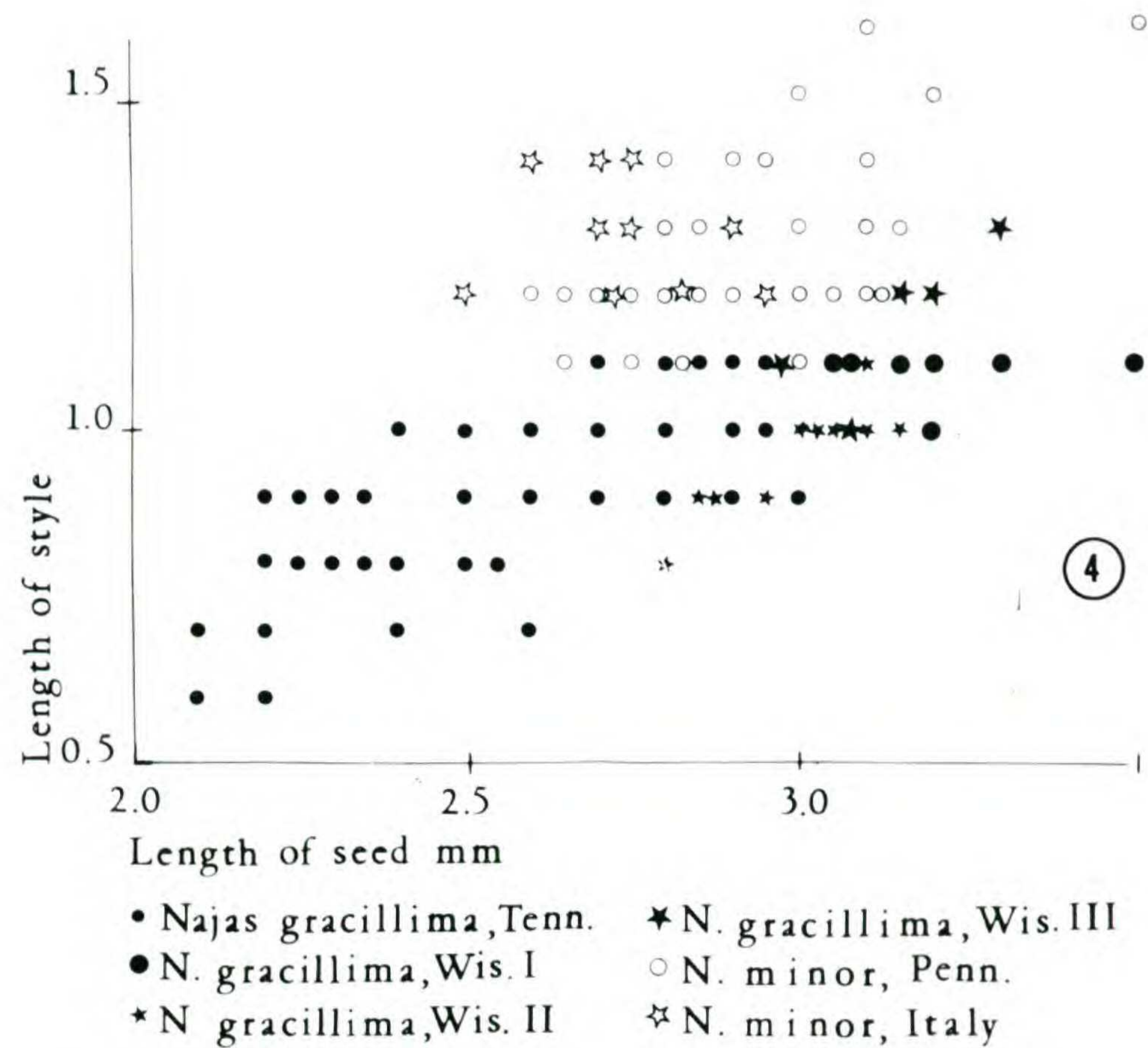
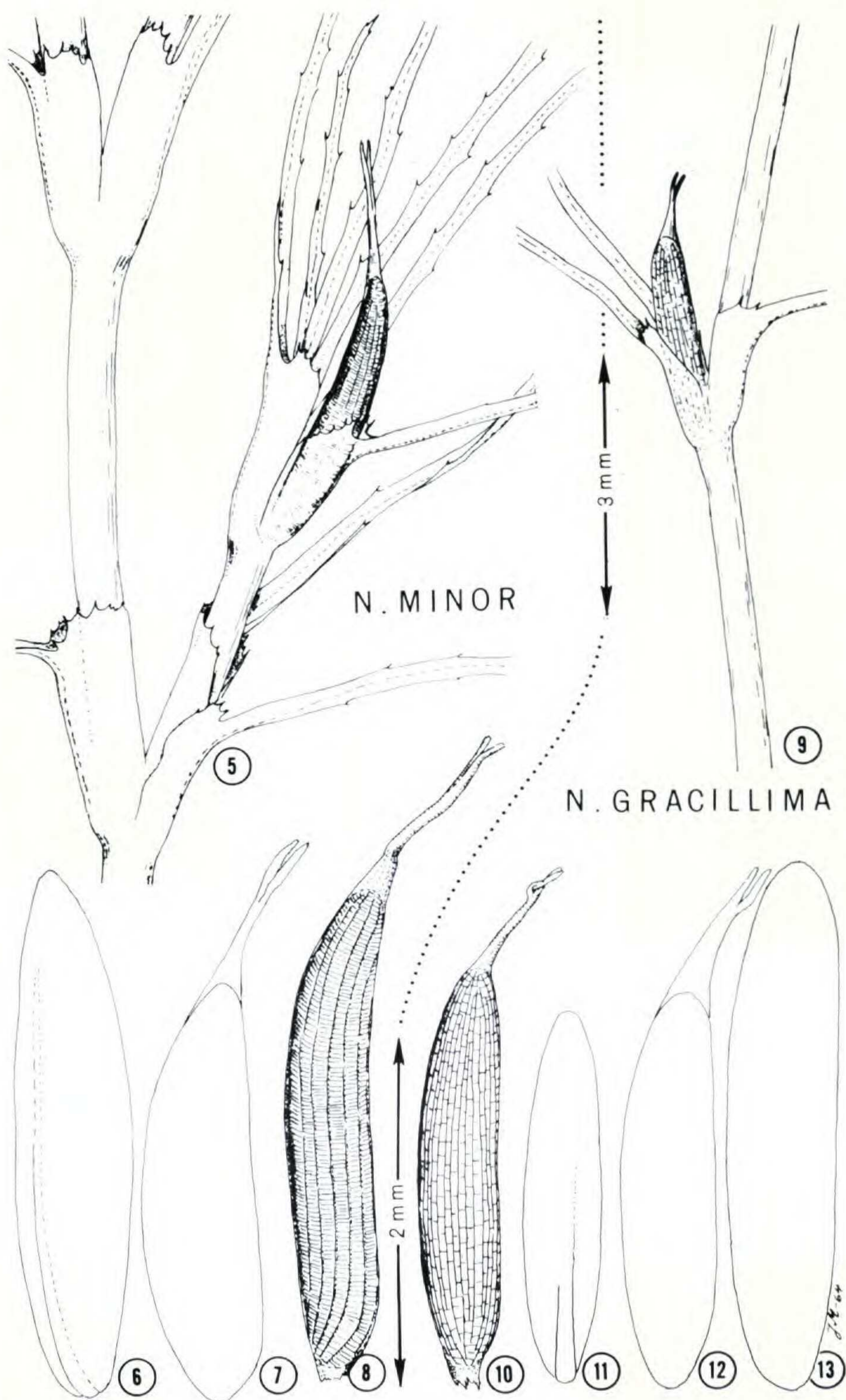


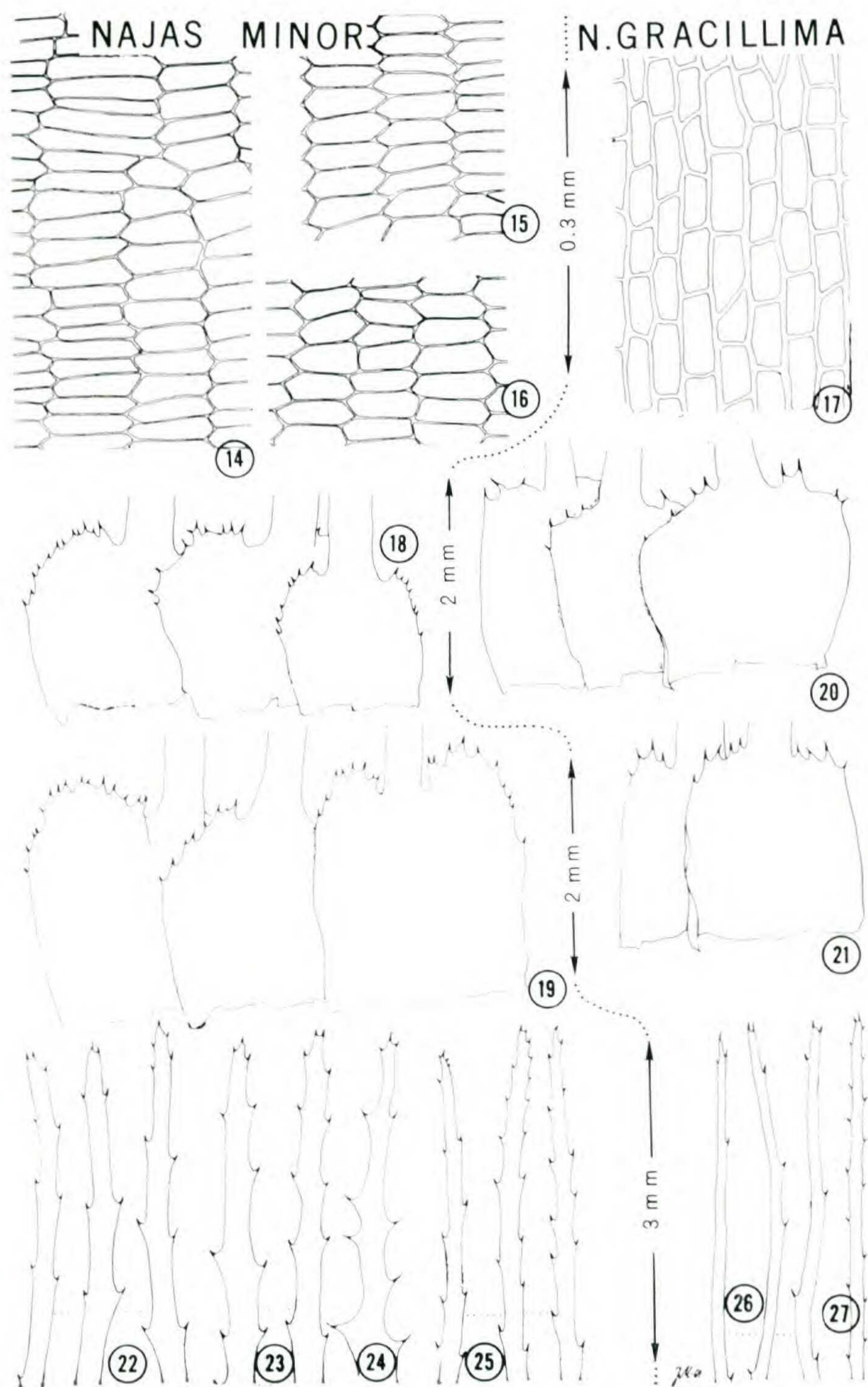
Fig. 4 The style to seed ratio of *Najas minor* and *Najas gracillima*.

reported as 120 cm high (Baumann 1911, p. 160). The number of spinules in leaves also varies and has little if any value in distinguishing these two species.

Najas minor was discovered in America by Muenscher and Clausen in the Hudson River in 1934, and Clausen (1936, p. 338) considered the species an introduction from the Old World. No other localities were found by Muenscher and Clausen although *Najas* material of many eastern North American herbaria was studied (Clausen, 1936, p. 338). In the subsequent thirty years the known North American range of the species has expanded considerably, covering the eastern United States from Lake Ontario west to Illinois and south to northern Florida (cf. Fig. 3,



Figs. 5-13. *Najas minor*: Fig. 5 fruiting branch, Fig. 6 seed, Fig. 7, 8, fruit. *Najas gracillima*: Fig. 9 fruiting branch, Fig. 10, 12 fruit, Fig. 11, 13 seed.



Figs. 14-27. *Najas minor*: Fig. 14, 15, 16 uppermost cell layer of seed coat, Fig. 18, 19 sheathing base of leaf, Fig. 22, 23, 24, 25 tip of leaf.

Najas gracillima: Fig. 17 uppermost cell layer of seed coat, Fig. 20, 21 sheathing base of leaf, Fig. 26, 27 tip of leaf.

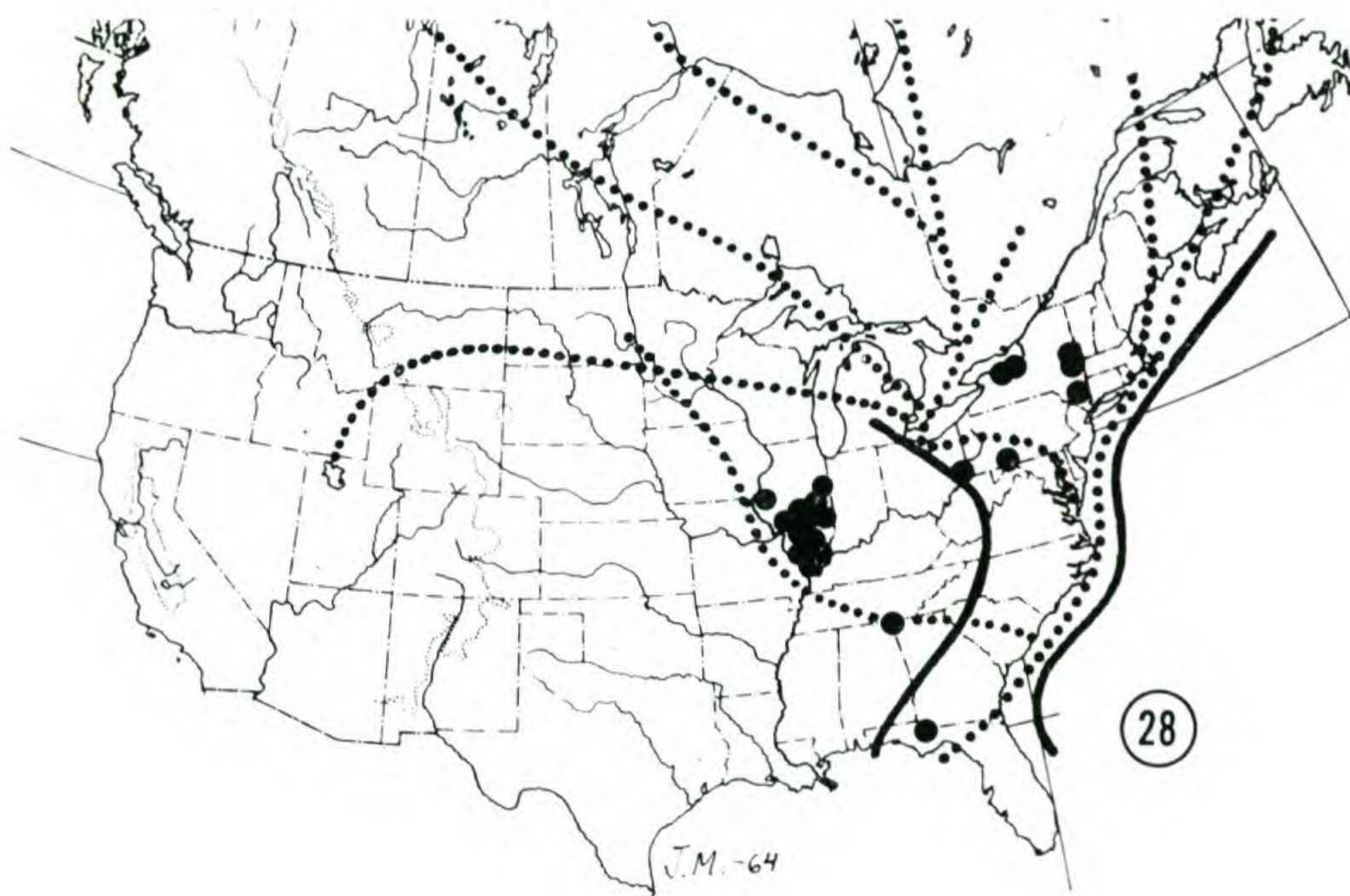
also Stookey, Fore, and Mohlenbrock 1964; Fore and Mohlenbrock 1966). How has this happened? The most important aid in dispersal might have been waterfowl. This factor has been discussed by Chase (1947, pp. 93-97). Shipping might also have been of importance in certain areas, e.g. in New York State as suggested by Chase (1947, p. 94), who reported *N. minor* from the New York State Barge Canal. It would be interesting to know the fate of the *N. minor* material thrown into Cayuga Lake off the Canoga Marshes" (Clausen 1936, p. 338) by W. C. Muenscher in 1935. Some later collections came from the same county, not far from the lake in question!

Most naiads, including *N. minor*, are highly fertile and produce great quantities of fruits, which make them an important food source for ducks, especially since the vegetative parts are eaten too. In the extensive material studied by Martin and Uhler (1939, pp. 9-12) *Najas* as a food source for ducks ranks eighth in importance in the United States and Canada, tenth in "the Atlantic region," and fifth (*N. flexilis*) in "the eastern region". It is likely that submerged plants are relatively more important to diving ducks, and that helophytes, lemnaeids, and nymphaeids are more important to the non-diving ducks. According to Martin and Uhler (1939, pp. 8, 12) 29% of inland divers in North America predominantly feed on plants (excluding the Greater Scaup Duck, see Cottam 1939, p. 33) and in "the eastern region" 52% of the divers eat primarily plants. *Najas minor*, however, growing in many localities on mud flats in shallow water (Baumann 1911, p. 161; Clausen 1936, pp. 337), is available also to non-diving ducks, and even to shore birds.

According to Lincoln (1935) there are four important flyways of waterfowl in North America: the Atlantic, the Mississippi, the Central, and the Pacific. As seen in Fig. 28 the localities of *N. minor* match very well with the Atlantic and Mississippi flyways on the map.

Chase (1947, p. 97) finds "extremely suggestive" the fact that the collected localities of *N. marina* in the Midwest,

The Atlantic Flyway of Waterfowl
with tributary migration routes (after LINCOLN)
And Localities of *Najas minor*



New York, and Florida are along the Atlantic flyway of waterfowl. This is also an interesting consideration with respect to dispersal of *N. minor*. The distributions of these two species in Europe are similar in freshwater, even if *N. minor* is rarer in the north and more common in the south (Graebner, cited in Backman 1951, p. 9). Furthermore, *N. minor* is "öfters mit *N. marina* (sensu lato) vergesellschaftet" (Glück, cited in Backman 1951, p. 10. See also Kolesnikova 1965, p. 188). In addition, *N. marina* is one of the plants occurring most frequently with *N. minor* in Pliocene and interglacial deposits (Backman 1951, p. 15; Tralau 1959, pp. 401-402).

Furthermore, the first findings of *Najas minor* in America are from the area of several *N. marina* localities. Clausen (1939, p. 179) reports frequent *N. marina* collections from Mendon Pond (Lake Ontario Watershed); Chase mentions *N. minor* from Mendon Pond, Big Mendon Pond, and 100

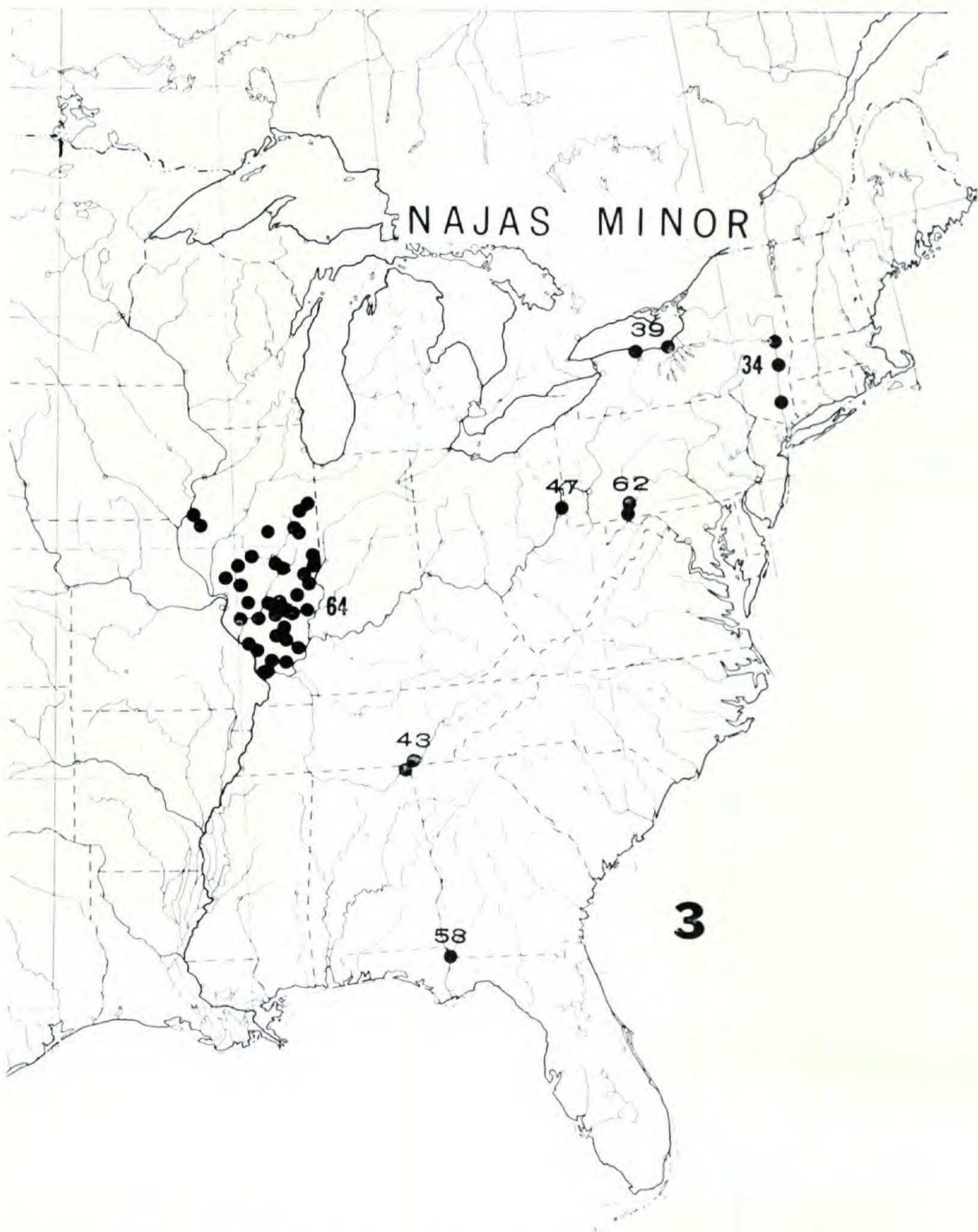


Fig. 3 Distribution of *Najas minor* in North America. Year of first collection indicated.

Acre Pond, all near Mendon, Monroe Co. (Chase, 1947, Table G: Collections deposited in the Cornell University Herbarium). Besides the Atlantic flyway, the Mississippi flyway may also have a significance in the further dispersal of this species. [This is supported by recent reports (Fore and

Mohlenbrock 1966; Stookey, Fore, and Mohlenbrock 1964; Winterringer 1966) of its great frequency (Fig. 3) in the southern half of Illinois. It is interesting that in a state as well-collected for aquatics as Wisconsin, of the three known stations of *N. marina*, two were collected in the past three years and all from near the shore of Lake Michigan, a well-known flyway for birds. (Sheboygan Co.: Random Lake, 1941, *Posekany s.n.* (WIS). Racine Co.: Long Lake, 1965, *Lind 88* (WIS). Kenosha Co.: Wind Lake, 1963, *Meriläinen 637 & 638* (WIS)). H.H.I.]

Many European localities of *N. minor* are associated with great, slow rivers, or oxbow lakes of the Rhine in Germany, the Danube in Austria, the Oder in Poland, and the Volga in the Soviet Union. This suggests a considerable tolerance to pollution. In most cases *N. minor* localities are also in large rivers in America (the Hudson, the Ohio, and the Tennessee Rivers) and the species is, according to Chase (1947, p. 95) much more tolerant of polluted conditions than *N. flexilis*.

We have already referred to some plants occurring with *N. minor*. Some more data will yet be given, even though there are risks in comparing floras of localities studied by different investigators using different methods for different purposes. Certainly also the size of localities is very variable. We do not always know the identity of the ecological requirements of plants reported under the same name from Europe and America. It is hoped, however, that the co-occurring flora of *N. minor* gives some indication of the ecology of this species.

Tralau (1959, pp. 398-402) makes a most interesting comparison between the interglacial flora of Lichvin in the Kaluga district, Russia, reported by Sukatchev, and a recent local flora in the westernmost Ukraine, 1000 km to the south-west, studied by Kleopow. In both districts *N. minor* was reported. Not only the aquatic but the forest flora as well are identical. The aquatic species co-occurring with *N. minor* are *Najas marina*, *Potamogeton crispus*, *P. acutifolius*, *P. natans*, *Stratiotes aloides*, *Scirpus lacustris*, *Eury-*

ale ferox, *Ceratophyllum demersum* and *Trapa natans*. Only one species, *Euryale*, is absent from the modern Ukrainian flora, and Tralau (1959, p. 402) suggests that this extinction was caused by historical factors. He further states that the former climate in the Lichvin district "may have been more oceanic than it is now." In data collected by Backman (1951, p. 15) from 16 Pliocene and interglacial deposits, *N. minor* occurs with *Ceratophyllum demersum* in 14, *Alisma plantago* in 12, and with *Potamogeton trichoides*, *Najas marina*, and *Trapa natans* in 10 localities. *Najas minor* has been found from only very few post-glacial deposits, two of which are in Finland. *Trapa natans* occurs in both of these, and *Najas marina*, *N. flexilis*, and *N. tenuissima* have been located in one of them (Backman 1951, pp. 17-23).

In comparing three recent river localities of *N. minor*, two north of the Black Sea and one in Rostock, Germany,⁵ we find *Potamogeton crispus*, *Hydrocharis morsus-ranae*, *Sagittaria* s.(p.) and *Ceratophyllum demersum* in all of them, and *Potamogeton pectinatus* in Rostock and one of the Soviet Union localities. Found in both Soviet Union localities are *Typha latifolia*, *Spirodela polyrhiza*, *Lemna minor*, *Butomus umbellatus*, *Alisma plantago-aquatica*, *Cicuta virosa* and *Oenanthe aquatica*. In one of the localities occur *Najas marina* and *Trapa natans* (Backman, 1951, pp. 10-11).

From America, Clausen (1939, pp. 170, 175) reports *N. minor* from Braddock Bay and Sterling Pond, both of which connect with Lake Ontario. The associated flora in both places includes *Typha latifolia*, *T. angustifolia*, *Potamogeton pusillus*, *Elodea canadensis*, *Vallisneria americana*, *Spirodela polyrhiza*, *Lemna trisulca*, *L. minor*, *Wolffia punctata*, *Heteranthera dubia*, *Ceratophyllum demersum*, and *Myriophyllum exalbescens*.

There is little information concerning the ecology of *N. minor*, but it may be partly summarized as follows: the species thrives in eutrophic waters, growing on mud bot-

⁵Only place in Europe where *N. minor* occurs in slightly brackish water (Backman, 1951, p. 10).

toms at a depth of one to more than ten feet of water. Often associated with large rivers or blind river-beds (oxbow lakes) it profits by river "improvement" projects in America, and tolerates pollution in some degree. The fruits resist considerable drought.

Acknowledgements

The writer wishes to express his sincere appreciation to Professor Hugh H. Iltis, Curator of the University of Wisconsin Herbarium, for all his advice and encouragement, for the inspiring working environment and especially for the valuable additions to up-date the paper during the years of editing. Without his help this paper could not have been written.

Best thanks are also expressed to Miss Doris Bruch and Brian Marcks for much editorial aid, to Keith Roe for supporting travel to the eastern herbaria, and to the curators of the various herbaria cited with the collections for permission to study the collections. Thanks are also due to Prof. Dr. Kaj Berg, director of the Freshwater Biological Laboratory of the University of Copenhagen, Hillerød, Denmark, where the last part of the work was done.

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LOCALITIES OF NAJAS MINOR⁶

(See Clausen, 1936, 1939 and Chase 1947)

NEW YORK: A. Drainage basin of Hudson River: ALBANY Co. Watervliet Reservoir, Sept. 3, 1934, *Muenscher & Clausen 4282* (CU). COLUMBIA Co. About one mile south of Stuyvesant, Aug. 28, 1934, *Muenscher & Clausen 4280* (CU). In channel west of Rogers Island, Hudson River, Sept. 1, 1936, *McVaugh 4460* (GH). Kinderhook Lake, Aug. 26, 1942, *Chase NY-50* (CU). Kinderhook Lake, Sept. 18, 1946, *Chase NY-205* (CU). DUTCHESS Co. Mouth of Wappinger Creek, Hudson River, New Hamburg, Aug. 31, 1936, *Muenscher & Curtis 5502 & 5503* (GH, WIS). Mouth of Wappinger Creek, Hudson River, Aug. 28,

⁶Many specimens have been seen in other herbaria than mentioned in this paper before the species became of special interest to the writer. The specimens in CU, the Cornell University Herbarium, and those recently collected from Illinois were not examined by the author.

1942, *Chase* NY-57 (CU). RENSSELAER Co.: Junction of Mohawk and Hudson Rivers, Troy, Sept. 10, 1935, *Muenschner & Curtis* 4826 (GH). SARATOGA Co: Mouth of Mohawk River at Waterford, Aug. 21, 1934, *Muenschner & Clausen* 4279 (CU). Mouth of Mohawk River at Waterford, Aug. 22, 1934, *Muenschner & Clausen* 4281 (GH). Backwater of Mohawk River, Waterford, Sept. 10, 1935, *Muenschner & Curtis* 4825 (GH). Hudson River, Mechanicsville, Aug. 7, 1938, *Muenschner & Justice* s.n. (GH, WIS). Hudson River above Mechanicsville, Aug. 27, 1942, *Chase* NY-44 (CU). Junction of Mohawk and Hudson Rivers, Aug. 27, 1942, *Chase* NY-45 (CU). Waterford, Sept. 17, 1946, *Chase* NY-202 (CU). B. Lake Ontario watershed: CAYUGA Co: Sterling Pond, connected with Lake Ontario by a narrow channel, North Fair Haven, Sterling Township, Aug. 10, 1939, *Clausen & Hinkey* 4326 (GH, NY). Menard Memorial Bridge, Seneca River, Sept. 1, 1942, *Chase* NY-65 (CU). MONROE Co: East side of Salmon Creek Inlet to Braddock Bay, Greece Township, Aug. 27, 1939, *Clausen & Hinkey* 4264 (GH, NY). 100 Acre Pond, Mendon, July 27, 1946, *Chase* NY-176 (CU). SENECA Co: Menard Memorial Bridge, Seneca River, July 10, 1946, *Chase* NY-105 (CU). Chase (1947) reports in text the following localities that are not in Table G, which was used in the above list: New York Barge Canal, Big Mendon Pond (p. 38), and Mendon Pond (p. 90). PENNSYLVANIA: BEDFORD Co: Shallow water, $\frac{3}{4}$ miles south of Schellsburg, Aug. 27, 1962, *Berkheimer* 21371 (PENN, WIS). Edge of dam, $3\frac{3}{8}$ miles south of Centerville, Sept. 18, 1962, *Berkheimer* 21584 (PENN). WEST VIRGINIA: OHIO Co: Ohio River, east side of Wheeling Island, shore along north end of island, Sept. 26, 1947, *Bartholomew* s.n. (GH, WVA: Core, private communication⁷). TENNESSEE: MARION Co: July 17-23, 1944, *Muenschner & Isely* s.n. (WVA: Core, private communication). Hales Bar Reservoir, near dam, July 18, 1944, *Isely* s.n. (US). ALABAMA: JACKSON Co: Goosepond. Guntersville Reservoir, July 2, 1943, *Isely* s.n. (GH, NY). FLORIDA: JACKSON Co: Lake Seminole, north of Sneads, Oct. 28, 1958, *Godfrey* 57873 (FSU⁸, GH, NY). Lake Seminole, north of Sneads, Aug. 16, 1961, *Godfrey* 61393 (FSU, NY). ILLINOIS: (In view of the very large number of Illinois collections of *Najas minor*, almost all of which are in the Illinois State Museum Herbaria, only the first collection made in each county is listed, H.H.I.) ALEXANDER Co: Horseshoe Lake, Olive Branch, June 22, 1964, *Allen*. CHAMPAIGN Co: R. D. Kibler farm, $\frac{1}{2}$ mile south of Mayview, July 20, 1965, *Fritz*. CLARK Co: Lincoln Trail Lake, 2 miles south of

⁷Thanks are expressed to Dr. Core for his help during the study.

⁸The special thanks of the writer are due to Dr. Godfrey for the excursion to the lakes of northern Florida and for his kindness during herbarium study. This trip was partly supported by the J. J. Davis Fund, of the Department of Botany, University of Wisconsin.

Marshall, July 27, 1964, *Miller*. CLINTON Co: Trenton Sportsman's Club, 4 miles north of Trenton, Aug. 11, 1964, *Miller*. CRAWFORD Co: Country Club Pond, Robinson, Aug. 11, 1965, *Fisher*. DEWITT Co: Weldon Spring Lake, 3 miles southeast of Clinton, June 23, 1965, *Stinauer*. EDGAR Co: Paris East Lake, Paris, July 27, 1965, *Fritz*. FORD Co: Hopples Pond, 6 miles northwest of Roberts, June 15, 1965, *Hiltobran*. FRANKLIN Co: West Frankfort New Reservoir, 1 mile southwest of Thompsonville, July 9, 1964, *Allen*. GALLITIN Co: Pounds Hollow Lake, 5 miles northeast of Karbers Ridge, Aug. 4, 1964, *Allen*. GREENE Co: Greenfield City Lake, 1 mile east of Greenfield, Aug. 4, 1964, *Lockhart*. HAMILTON Co: McLeansboro Reservoir, 1 mile west of McLeansboro, Sept. 14, 1965, *Allen*. HENDERSON Co: Smith Pond, 5 miles southwest of Raritan, Aug. 3, 1965, *Russell*. IRIQUOIS Co: Storm's Pond, 3 miles northeast of Crescent City, Aug. 26, 1964, *Zebrun*. JACKSON Co: Lake Murphysboro, 1 mile west of Murphysboro, June 24, 1964, *Miller*. JEFFERSON Co: Miller Lake, 7 miles northeast of Mt. Vernon, July 29, 1964, *Fisher*. JOHNSON Co: Ferne Clyff Lake, 1½ miles southwest of Goreville, June 9, 1964, *Allen*. McDONOUGH Co: Argyle Lake, 2 miles north of Colchester, June 23, 1964, *La Buy*. MACOUPIN Co: Staunton City Lake, 2 miles north of Staunton, June 22, 1964, *Lopinot*. MADISON Co: Henry Haag Pond, 2 miles northeast of Godfrey, Sept. 3, 1964, *Lockhart*. MARION Co: Salem Reservoir, northwest edge of Salem, July 13, 1964, *Fisher*. POPE Co: Lake Glendale, 3 miles south of Glendale, Aug. 4, 1964, *Allen*. PULASKI Co: America Lake, 4 miles east of Mounds, Aug. 5, 1964, *Allen*. RANDOLPH Co: Randolph County Lake, 5 miles northeast of Chester, June 15, 1964, *Miller*. RICHLAND Co: Albert Ax Lake, 9 miles northwest of Olney, Aug. 24, 1965, *Fisher*. ST. CLAIR Co: Al Reibel Lake, 4 miles southeast of Freeburg, June 14, 1965, *Miller*. SALINE Co: John Griffin Pond, 3 miles west of Raleigh, Sept. 14, 1964, *Allen*. SANGAMON Co: Carl Moore Pond, 2 miles west of Rochester, Aug. 31, 1964, *Rogers*. SHELBY Co: Bessie Grover Pond, 5 miles east of Strasburg, July 19, 1965, *Fritz*. WABASH Co: Highland Hills Water, 2½ miles southeast of Lancaster, Aug. 23, 1965, *Fisher*. WASHINGTON Co: Washington County Conservation Area Lake, 5 miles south of Nashville, July 18, 1966, *Dolbeare* 886. WAYNE Co: Artificial Lake, Johnsonville, Oct. 15, 1963, *Lopinot*.

ILLUSTRATIONS

Figs. 1, 2, 8, and 10 were drawn using dry material; for all the other illustrations the plants were resoftened. Fig. 6-27 were drawn with the aid of camera lucida. The following material was used for figs. 5-27. NAJAS MINOR: Pennsylvania, *Berkheimer* 21371 (PENN), figs. 5, 8, 16, 19, 25; Torino, Italy, Aug. 22, 1909, *Ferrari* s.n. (WIS), figs. 6, 15, 18, 22; New York, *Muenschler & Curtis* 5503 (WIS), figs. 7, 14, 23; Pennsylvania, *Berkheimer* 21584 (PENN), fig. 24. NAJAS GRACIL-LIMA: Tennessee, Chickasaw State Park, Aug. 18, 1954, *Iltis* s.n.

(WIS), figs. 9, 10, 11, 12, 17, 20, 26; Massachusetts, Norfolk Co., Sept. 22, 1937, *Seymour 5023* (WIS), figs. 13, 21; Massachusetts, Franklin Co., Aug. 3, 1925, *Seymour 2472* (WIS), fig. 27.

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